UNIT 5:
PACKAGING, TRANSPORTATION AND STORAGE

LEARNING OBJECTIVES

By the end of this section, participants will be able to:

- Identify three types of packaging for radioactive materials
- Describe package testing procedures for radioactive materials containers
- Describe the type of information required on radioactive placards and labels
- List five types of radioactive shipments
- Explain how radioactive materials are transported
- Identify six types of radioactive waste
- Explain how radioactive materials are stored

PACKAGING

All shipments of radioactive materials, whether from industry or government, must be packaged and transported according to strict Federal regulations. These regulations protect the public, transportation workers, and the environment from potential exposure to radiation.

Types of Packaging

The most effective way to reduce the risks associated with transporting radioactive material is to follow the appropriate packaging standards specified by DOT and, when required, NRC regulations. The type of packaging used is determined by the activity, type, and form of material to be shipped. Depending on these factors, radioactive material is shipped in one of three types of containers:

- Industrial packaging
- Type A packaging
- Type B packaging

Industrial Packages

Materials that present little hazard from radiation exposure, due to their low level of radioactivity, are shipped in **industrial** packages. These are also known as **strong, tight** packages. This type of container will retain and protect the contents during normal transportation activities. Slightly contaminated clothing, laboratory samples, and smoke detectors are examples of materials that may be shipped in industrial packages.

Industrial containers can range from cardboard boxes to sturdy wooden or steel crates

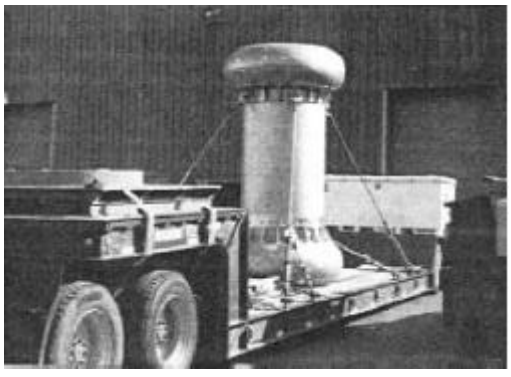
Type A Packages

Radioactive materials with higher specific activity levels are shipped in Type A packages. These packages must demonstrate their ability to withstand a series of tests without releasing the contents. Regulations require that the package protect its contents and maintain sufficient shielding under conditions normally encountered during transportation. Typically, Type A packages are used to transport **radiopharmaceuticals** (radioactive materials for medical use) and certain regulatory-qualified industrial products.

Type A packages are made of fiberboard, wood, or steel and often have some shielding material for LSA radioactive materials

Type B Packages

Radioactive materials that exceed the limits of Type A package requirements must be shipped in Type B packages. Shippers use this type of package to transport materials that would present a radiation hazard to the public or the environment if there were a major release. For this reason, a Type B package design must not only demonstrate its ability to withstand tests simulating normal shipping conditions, but it must also withstand severe accident conditions without releasing its contents.



Type B cask used for transporting spent reactor fuel

Type B cask specifically designed for rail transportation

Type B packages are used to transport materials with high levels of radioactivity, such as spent fuel from nuclear power plants. These large, heavy packages provide shielding against the radiation. The size of Type B packages can range from small containers to those weighing over 100 tons.

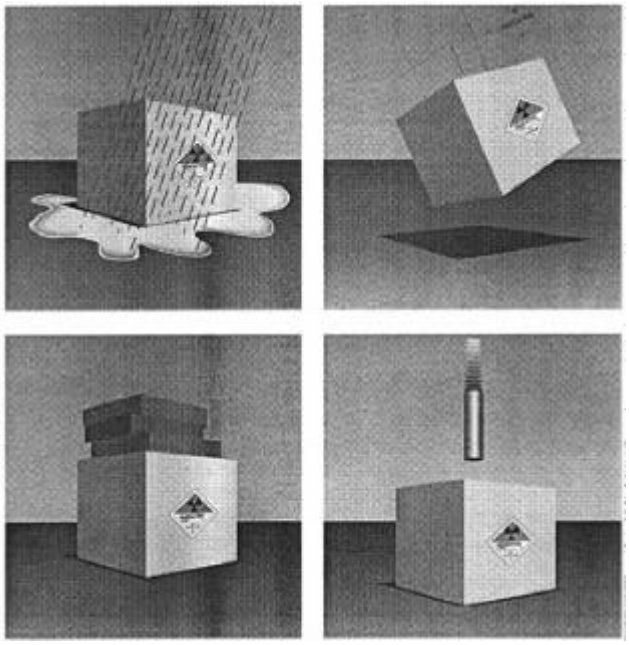
Package Testing

Radioactive materials are packaged according to their form, quantity, and concentration. DOE ensures that when radioactive materials are transported, they are packaged carefully to protect the public, transportation workers, and the environment. DOT and NRC regulate the testing of radioactive material package designs. DOT is responsible for specifying the required test conditions for packages. NRC certifies that packages designed for materials with higher levels of radioactivity, such as spent fuel, meet DOT's test requirements.

Type A Packaging Testing

Type A package designs must withstand four tests simulating normal transport conditions. These tests include:

- Water spray for one hour to simulate rainfall of two inches per hour
- Free-fall drop test onto a hard, flat surface
- Compression of at least five times the weight of the package
- Penetration test by dropping a 13 pound, 1.25 inch diameter bar vertically onto the package from a height of 3.3 feet



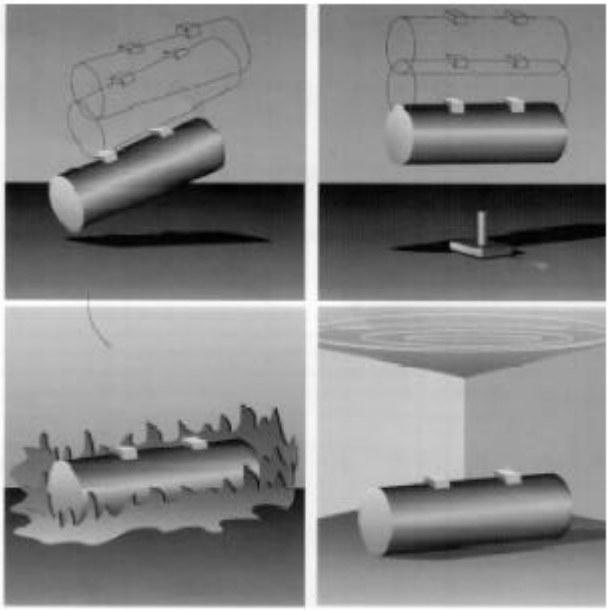
Type A package designs must withstand four tests simulating conditions of normal transport, including water spray (rain), drop, compression, and penetration tests (handling conditions)

The NRC has established strict performance standards and testing requirements for Type B package designs. Computer analyses and scale model testing demonstrate the structural integrity of the design.

Type B Packaging Testing

Type B packaging must withstand Type A packaging and four additional tests:

- A 30-foot drop onto a flat, unyielding surface so that the package's weakest point is struck
- A 40-inch free drop onto a 6-inch diameter steel rod at least 8 inches long, striking the package at its most vulnerable spot
- Exposure of the entire package to 147 ^{o}F for 30 minutes
- Immersion of the package under 15 feet of water for at least 8 hours



Type B packages must withstand four more tests simulating severe accident conditions: impact, puncture, heat, and water immersion

Crash tests using actual spent fuel package prototypes have been used to verify the accuracy of the computer models. For example, a truck carrying a prototype shipping package was crashed into a 900-ton concrete wall at 81 miles an hour. The truck was demolished, but the package was damaged only slightly.

Special Form and Fissile Materials

Special form materials are radioactive isotopes enclosed in sealed capsules. They are designed to withstand a fire and a high degree of damage, so they are rarely a problem unless the source is removed from the capsule. If you suspect that a source has been removed from the capsule, stay away from the area and notify the appropriate radiation authorities.

Containers for fissile materials are also designed to withstand a great deal of stress, so it is not likely these materials will present a hazard. These materials are not flammable. In addition, the packaging is designed to withstand total engulfment by fire at temperatures of 1475° Fahrenheit for a period of 30 minutes.

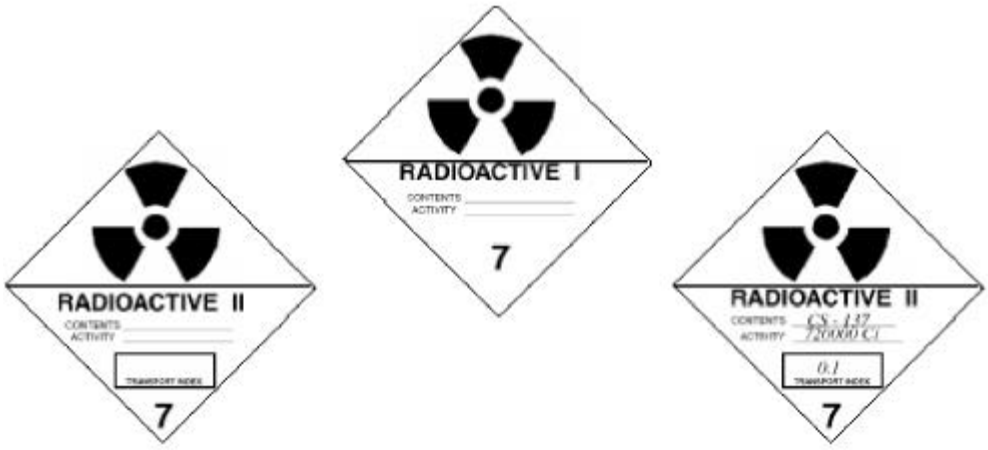
Placards and Labels

Placards are required on vehicles transporting one or more packages bearing Radioactive - Yellow III labels, even if the cargo is in Type A packages. High level radioactive materials, such as spent nuclear fuel, require a diamond-shaped placard within a larger white square with a black border.

Non-bulk containers of radioactive materials must be marked with the shipping names, product identification, and shipper's name and address. Labels identify the contents and radioactivity level according to three categories:

- **Radioactive - White I:** almost no radiation. The maximum allowable radioactivity is 0.5 mrem/hr on the package surface.
- **Radioactive - Yellow II:** low radiation levels. The maximum allowable radioactivity is 50 mrem/hr on the package surface, and one mrem/hr at three feet from the package.
- **Radioactive - Yellow III:** higher levels. Maximum allowable radioactivity is 200 mrem/hr on the package surface, and 10 mrem/hr at three feet from the package. This is required for fissile Class III materials or large quantity shipments of any radiation level. (Fissile refers to elements in which a fission reaction can be induced. This reaction will cause fissile atoms to become unstable and release energy and radiation.) Vehicles carrying packages with Yellow III labels must have a radioactive placard on both sides and both ends of the vehicle.

Each of these labels also includes lines on which the contents are identified and the level of radioactivity is stated in terms of curies. The Yellow II and Yellow III labels have additional items called the **transport index box.** (The top of the diamonds for Radioactive II and III are actually yellow.) For the majority of shipments, the number in the transport index box indicates the maximum radiation level (measured in mrem/hr) at one meter (3.28 feet) from the surface of the package.



In the examples above, a transport index of 0.1 on the Radioactive III label indicates that radiation measured 1 meter from the surface of the package should be less than 0.1 mrem/hr. With the exception of exclusive use shipments, the maximum transport index for any shipment is 10 mrem/hr. Packages that carry radioactive materials are designed to absorb radiation if it is
released from the container. There are other regulations pertaining to the transport index as well, though not as commonly used.

Regulations limit exposure by restricting the total of all the transport indexes on any one vehicle, usually to less than 50. Exposure is also limited by requiring tests for radioactive contamination on the outside of the packages before shipping.

If a total shipment exceeds 200 mrem/hr, the vehicle must be designated exclusively for the purpose of transporting that shipment.

Above the transport index is the **contents** line, which identifies the material inside the package.

Under contents is the **activity** line, which gives the level of radiation in becquerels or curies.

Reusable shipping containers that are empty, but possibly contaminated inside, are labeled with the word “empty.”

TRANSPORTATION

Radioactive materials are shipped safely every day. DOE regulations covering these materials strictly control the types that can be carried, their quantities, and the packaging. In addition, hazard communication standards help ensure that those who handle or come into contact with these materials – including emergency responders – will be able to identify the cargo and understand the hazards.

Types of Shipments

Radioactive materials that are shipped include:

- Uranium ores
- Nuclear fuel assemblies
- Spent fuel
- Radioisotopes
- Radioactive waste

Uranium ores and associated chemical products are shipped from mines and mills to purification processors. Irradiated material is shipped to manufacturers of metal and ceramic fuel assemblies.

Nuclear fuel assemblies are the source of energy for commercial nuclear power plants and their production of electricity. Fuel elements are also produced for research reactors and national defense programs.

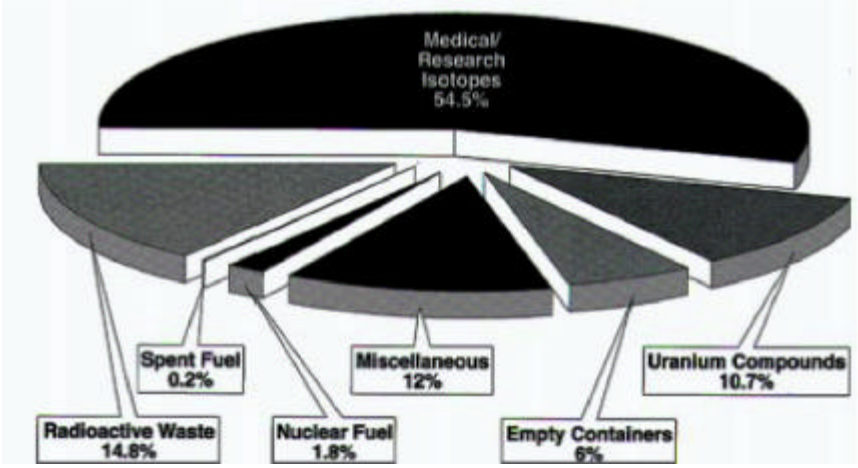
Spent or "used" fuel is moved to a geologic repository for permanent disposal. Commercial spent fuel is now being temporarily stored at power plants, while Government-owned spent fuel from test or research reactors is stored at DOE sites.

Radioisotopes are transported from reactors to medical facilities, research laboratories and defense sites, as well as to a variety of industries and manufacturing facilities.

Radioactive waste results from processes that use radioactive materials and must be transported to storage or disposal sites.

Transportation accidents involving radioactive materials are very rare. Of 500 billion total shipments in this country every year, 100 million (.02%) contain hazardous materials, and only 3 million (.0006%) contain radioactive materials.

Hospitals, factories, research facilities, nuclear power plants and other users of radioactive material are often at some distance from the locations that supply this material. In addition, they are often far from the waste storage and disposal sites.



Radiological Shipments by Industry

Strict federal regulations established and enforced by the Department of Transportation (DOT) and the Nuclear Regulatory Commission (NRC) govern the packaging, labeling, documentation and routing of shipments of radioactive materials. All modes of transportation (highway, rail, air or waterway) and all carriers (private or government) are covered by these regulations.

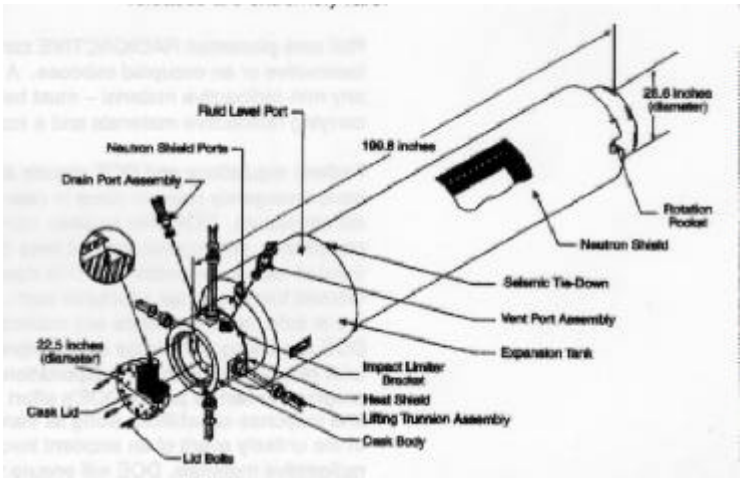
Transportation of Radioactive Materials by Highway

Most radioactive waste is shipped by highway cargo tanks. Trucks transport a wide variety of both low-level and high-level radioactive materials, including fission products used to manufacture nuclear fuel.

Tractor-trailer transporting radioactive cargo

Transportation of these materials is highly regulated. Among other restrictions, carriers are required to follow the most direct interstate route, bypassing heavily populated areas when possible.

When transportation incidents occoccur, they are most likely the result of a cargo tank accident. However, containers used for shipping high level radioactive materials are very strong, and releases are extremely rare.



Example of cask used to transport high-level spent reactor fuel

South Gate, CA, February 1993

A vial of potentially deadly radioactive cesium-137 was either lost or stolen while in transit along Interstate 5. The vial (measuring 3.5" by .75") was being shipped from northern California to South Gate. Cesium-137 is used to sterilize medical equipment. This material is usually encapsulated in two steel tubes and welded closed. Because of its high level of radioactivity, cesium-137 is stored underwater and must be remotely handled during use and loading for transport. Officials using a Geiger counter eventually found the small container beside an on-ramp to the Long Beach freeway. Had it not been for an anonymous tip, the container might not have been found. — "Hazardous Materials Emergencies," John R. Cashman, 1995

Transportation of Radioactive Materials by Rail

Rail is the second most frequent method of transporting radioactive materials. Generally, trains carry only large volumes of material, such as uranium hexafluoride.

Rail accidents can be particularly dangerous for two reasons. For one, extremely large quantities are involved. Secondly, a serious accident can damage several rail cars, resulting in combinations of hazardous materials.

The preferred method of shipping radioactive materials and waste is by unit train, which runs directly between its point of origin and its destination. It receives priority right-of-way and expedited switching, and does not receive or unload any additional cargo along the way. The radioactive loads are contained by a disposable liner and a hard cover and carried in gondola cars.

Rail cars placarded RADIOACTIVE cannot be placed next to a locomotive or an occupied caboose. A buffer car – loaded with any non-radioactive material – must be placed between a car carrying radioactive materials and a locomotive or caboose.

Federal regulations and DOE require shippers and carriers to have emergency plans in place in case an accident involving a rail car occurs. DOE also requires railroads to document their compliance with regulations and laws before and during shipment
of radioactive materials. This documentation ensures that railroad tracks and rail structures such as culverts and crossings are in safe condition before any materials are shipped. Also, DOE is working with states along shipment routes to train and brief responders on their transportation plans. This training program, in fact, is part of DOE's effort to increase awareness and response capabilities along its transportation routes. In the unlikely event of an accident involving DOE-regulated radioactive materials, DOE will ensure that any release is cleaned up, and that any other remedial actions are taken.

Transportation of Radioactive Materials by Air

DOT strictly limits air shipment of radioactive materials. One exception is radiopharmaceuticals. Radiopharmaceuticals are radioactive drugs used to diagnose or treat illnesses, and are frequently short-lived, small and light-weight. Often they must be delivered quickly to hospitals and medical laboratories, so air shipment is generally the best method.

Air shipment of radioactive materials is not regulated by the Code of Federal Regulations, as are most other methods. Regulations for air transport are issued by the International Atomic Energy Agency (IAEA).

With the exception of nuclear weapons, large quantities of radioactive materials are rarely shipped by air. The military and its contract carriers are notable exceptions, however.

Transportation of Radioactive Materials by Water

Only a small percentage of radioactive materials are shipped by water, primarily because this type of transportation is slow and geographically limited. Materials that are occasionally transported via waterways include spent nuclear fuel, uranium metal, uranium hexafluoride, and low-level waste. When shipped by water, these materials are identified as “marine pollutants” and noted as such on the manifest.

International water transport of radioactive materials is governed by the IAEA and the International Marine Organization (IMO). Transportation in US waters is regulated by DOT and NRC. In addition, DOE has conducted extensive tests to ensure the safety of ships carrying radioactive cargo.

Shipments that exceed a certain level of radioactivity must be shipped exclusively on vessels hired specifically for that purpose.

STORAGE

When radioactive materials are depleted of their usefulness, they are considered waste and must be stored at a government-approved disposal facility.

Storing Radioactive Waste

Each type of waste is sent to a disposal site that is appropriate for its characteristics.

High Level Waste

High level waste results from the reprocessing of spent nuclear fuel in a commercial or defense facility. Reprocessing can recover the usable radioactive materials for research and defense programs. High level waste is currently stored in underground tanks and vaults at government sites. Some of this waste will be solidified in a glass form, packaged in stainless steel canisters, and placed in heavily shielded casks for transport to a permanent geologic repository.

Spent Fuel

Spent fuel results from producing electricity at nuclear power plants or from operating other reactors such as research reactors. After the usable fuel has been expended, highly radioactive fuel assemblies remain.

The U.S. does not reprocess spent fuel from power plants, but has reprocessed spent fuel from many types of reactors in the past. Spent fuel is shipped as a solid, and is packaged in casks for transport. Currently, spent fuel is stored in pools of water, aboveground vaults, or concrete casks onsite at reactor or commercial power plants.

Spent fuel from DOE-owned reactors is stored where it is produced or at other DOE sites. Like high-level waste, spent fuel will eventually be shipped to permanent geologic repositories.

Under the Nuclear Waste Policy Act, DOE is responsible for transporting spent fuel from power plants, as well as defense-related high-level radioactive waste, to permanent repositories.

Transuranic Waste

Transuranic waste contains manmade elements heavier than uranium, thus the name trans (or beyond) uranic. Transuranic waste results from defense production activities and includes contaminated protective clothing, tools, glassware, and equipment. Most is now stored at government sites throughout the country. Although most transuranic waste is no more radioactive than low-level waste, it is radioactive for a longer period of time.

In the past, transuranic waste was shipped in rail cars, but shipments to the Waste Isolation Pilot Plant (WIPP) in New Mexico will be made by truck in a specially-designed packaging called the TRUPACT-II. WIPP is designed to demonstrate the disposal of transuranic waste in deep, geologically stable salt beds. If the demonstration project is successful, the site will become a permanent disposal facility for transuranic waste.

Low-Level Waste

Low-level waste results from research, medical, and industrial processes that use radioactive materials. Commercial power plant operations and defense-related activities, including weapons disassembly and cleanup of production sites, also produce some low-level waste. Low-level waste consists of contaminated rags, papers, filters, tools, equipment, and discarded protective clothing.

Low-level radioactive scrap metal from a building demolition at uranium processing facility

Typically, low-level waste contains small amounts of short-lived radioactive material dispersed in large quantities of non-radioactive material. It is far less hazardous than high-level waste and is usually packaged in sturdy wooden or steel crates and steel drums for shipment to storage or disposal sites.

Low-level waste is sent to disposal sites licensed by the U.S. Nuclear Regulatory Commission. Several commercial sites accept waste from producers of low-level waste, and some states have formed regional compacts to dispose of low-level waste when these facilities close. Sites have been established throughout the DOE complex for disposal of DOE low-level waste.

Mixed Waste

Mixed waste is waste that contains both hazardous chemical components and radioactive components and is subject to the requirements of the Atomic Energy Act and the Resource Conservation and Recovery Act. Mixed waste is treated, packaged, and shipped offsite to DOE or commercial disposal sites by most DOE facilities that produce it. Envirocare of Utah, Inc., recently began accepting DOE mixed waste shipments for disposal. The waste is encapsulated in melted recycled plastic and disposed of in an onsite landfill.

Uranium Mill Tailings

Uranium mill tailings are radioactive rock and soil byproducts from uranium mining and milling. Mill tailings contain small amounts of naturally occurring radium that decays and emits a radioactive gas, radon. When radon gas is released into the atmosphere, it disperses harmlessly. However, radon gas might be dangerous if it is inhaled in high concentrations over a long period of time. Uranium mill tailings are transported to several disposal facilities specifically designed to accept them. When the disposal site reaches capacity, it is sealed to prevent dispersion of radon gas.

UNIT 5
APPENDIX

Activity 5-1
Scenario

Time: 0930 Hours
Weather: Cloudy, wind out of the northeast.
Temperature 52°F

You receive a medical call from the dispatcher, a patient with difficulty breathing. You are sent to assist an ambulance enroute to a warehouse in an industrial park. You are to meet the caller at the loading dock on the east side of the warehouse.

Upon arrival, you notice very little activity. The company is Environmental Enterprises, Inc. This is a company which, among other things, cleans tanks and water blasts graffiti, provides deep well monitoring and does site clean-up and remediation.

On the loading dock you meet a mechanic who says he placed the emergency call for himself. His B/P is 162 over 98. Respirations are 18 and shallow. His chief complaint is respiratory distress and nausea.

He says he was working on the lighting in a trailer, trying to repair some fixtures and a short in the wiring. He has been at work since 0730 that morning, and in the trailer for about an hour. His ladder slipped while repairing the light on the ceiling of the trailer, causing him to fall against one of the containers. He landed on his side.

You send a fire fighter to the trailer to find out what is inside. The fire fighter returns and tells you no hazards are readily apparent. There is no product leaking onto the floor, nor are there any placards outside of the trailer. There are, however, several drums with hazardous waste stickers and what look like yellow and white labels. These containers were in the dark forward end of the trailer.

You decide to investigate a little further. On one of the drums, you can see the corner of a Radioactive-II label. You take a better look with your flashlight. The number .5 is written in the transport index box on the Radioactive-II label.

The ambulance is just pulling into the yard.

1. How would you characterize the scenario?

2. How would you treat the patient?

3. What hazards are involved?